Numerical and Theoretical Investigations of North Pacific Subtropical Mode Water with Implications to Pacific Climate Variability

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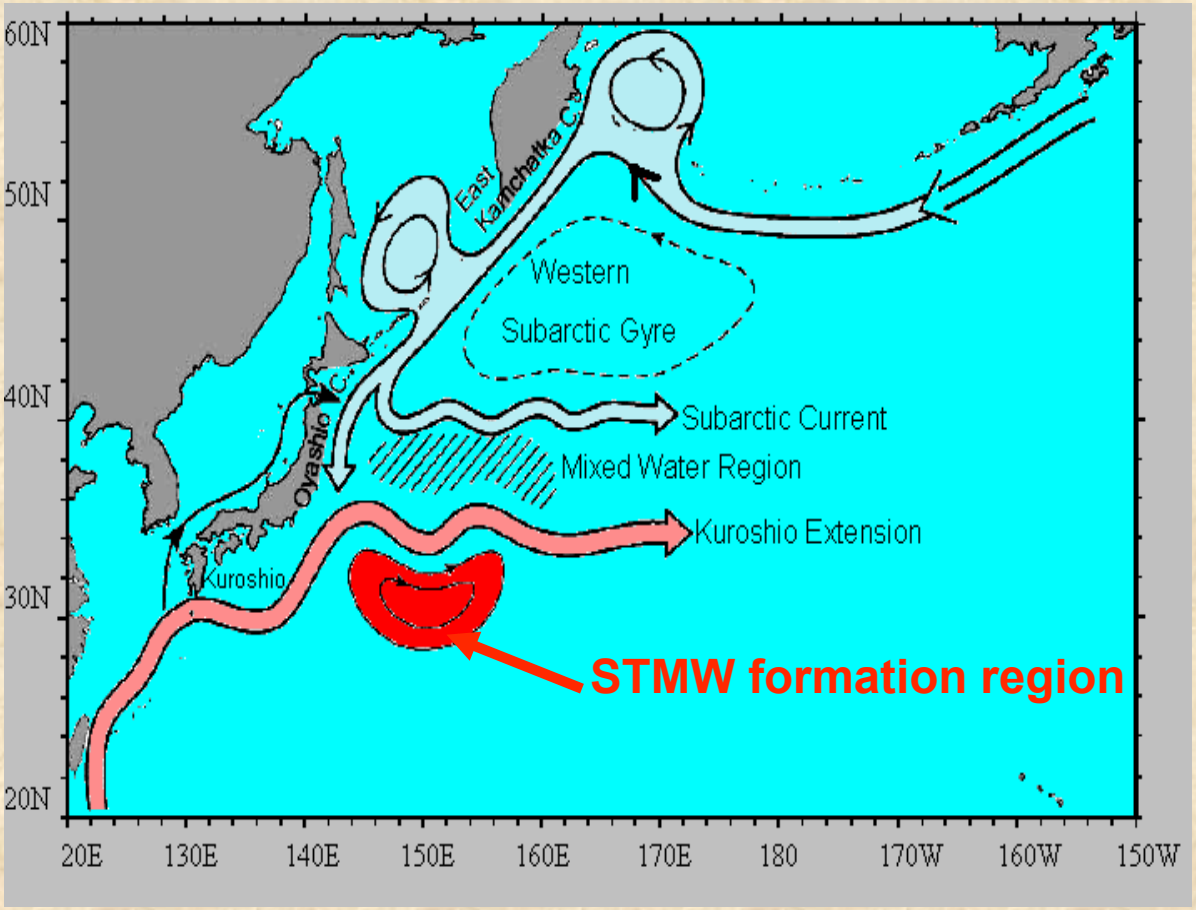
North Pacific Subtropical Mode Water (STMW)

Schematic current patterns in western North Pacific



Location: forms and resides south of Kuroshio Extension (KE)

Features:

-weakly stratified, low PV

-upper 500 m of the ocean water column

-inhabits thermostads between 16 and 19C

-salinity range of 34.65-34.8psu

-potential density values of 24.8-25.7 kg/m^3

(Masuzawa, 1969; Suga et al., 1990; Eitarou et al., 2004)

Questions

- STMW has known seasonal variability, but what is the variability of STMW on longer time scales?
- What is the relationship (if any) between low frequency STMW and established climate patterns in the Pacific?
- Dynamics behind it?

Model and Simulation Descriptions

MITgcm : 3D, z level, primitive equation OGCM (Marshall, 1997)

- ECCO2 (Cube 37) global-ocean and sea-ice simulation :

  -28-year spin-up prior to its initial January 1992 conditions, carried out by cycling through the 1992-2000 NCEP forcing converted to fluxes using model SST and the Large and Pond bulk formulae *(Large et al, 1995, Menemenlis, 2005)*

- θ, S, u, v

- Resolution: horizontal resolution: 1/6 lat x 1/6 lon; vertically, from surface to ~6km, 10 m resolution above 100 m and stretched to 95 m around 1000 m

- temporal coverage: 1992, Jan – 2006 Mar (171 months)

-Output hasn't been constrained by oceanic and seaice data yet

STMW definition

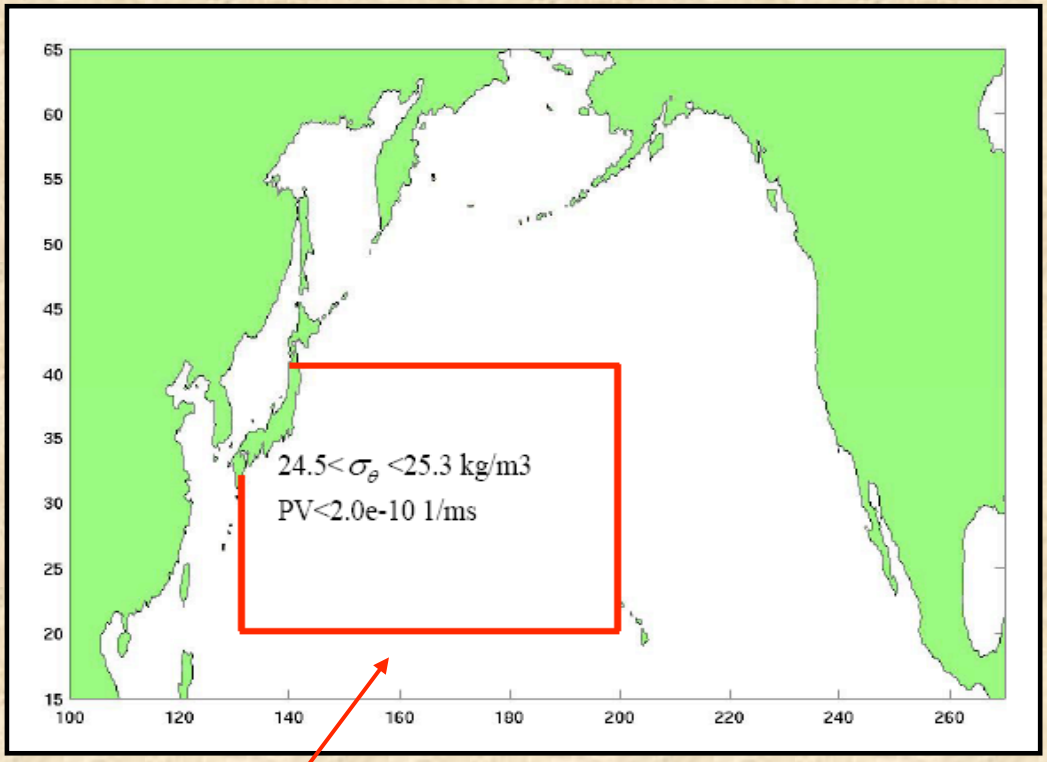
Definition in Cube37 simulation

- PV is less or equal to $2\times10^{-10}\,m^{-1}s^{-1}$

$$PV = -\frac{f}{\rho}\frac{\partial\sigma_\theta}{\partial z}$$

- potential density between 24.5~25.3 kg/m^3

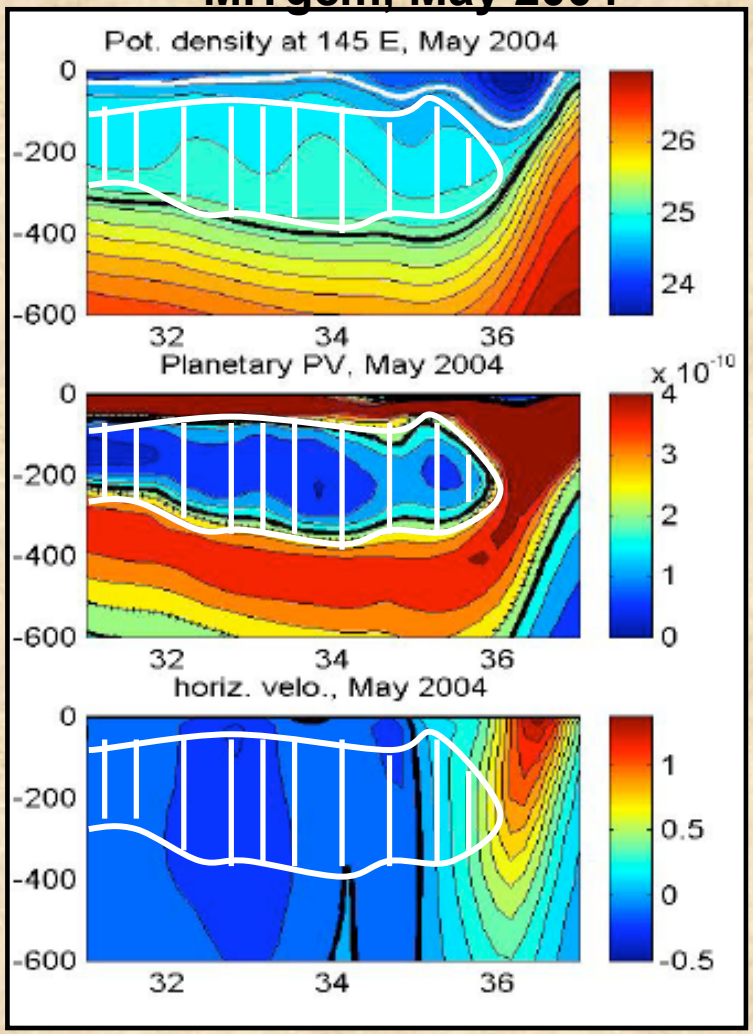
- region of 130E~ 200E, 20N~ 40N and east of islands of Japan



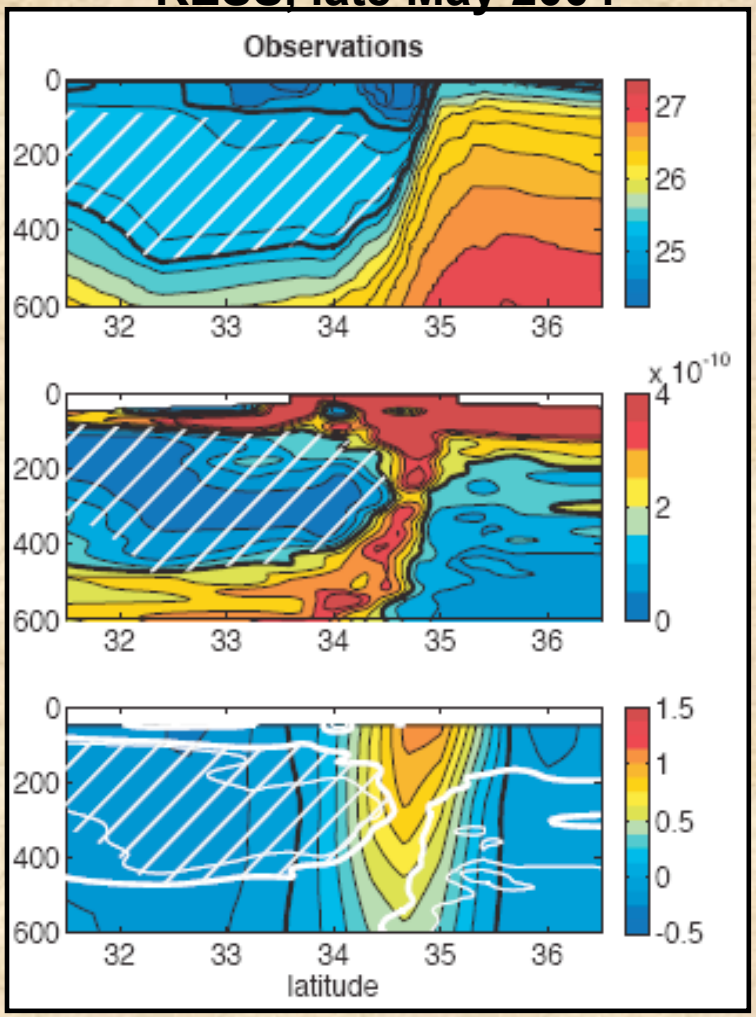
Defined STMW region

Compare with Observation

MITgcm, May 2004

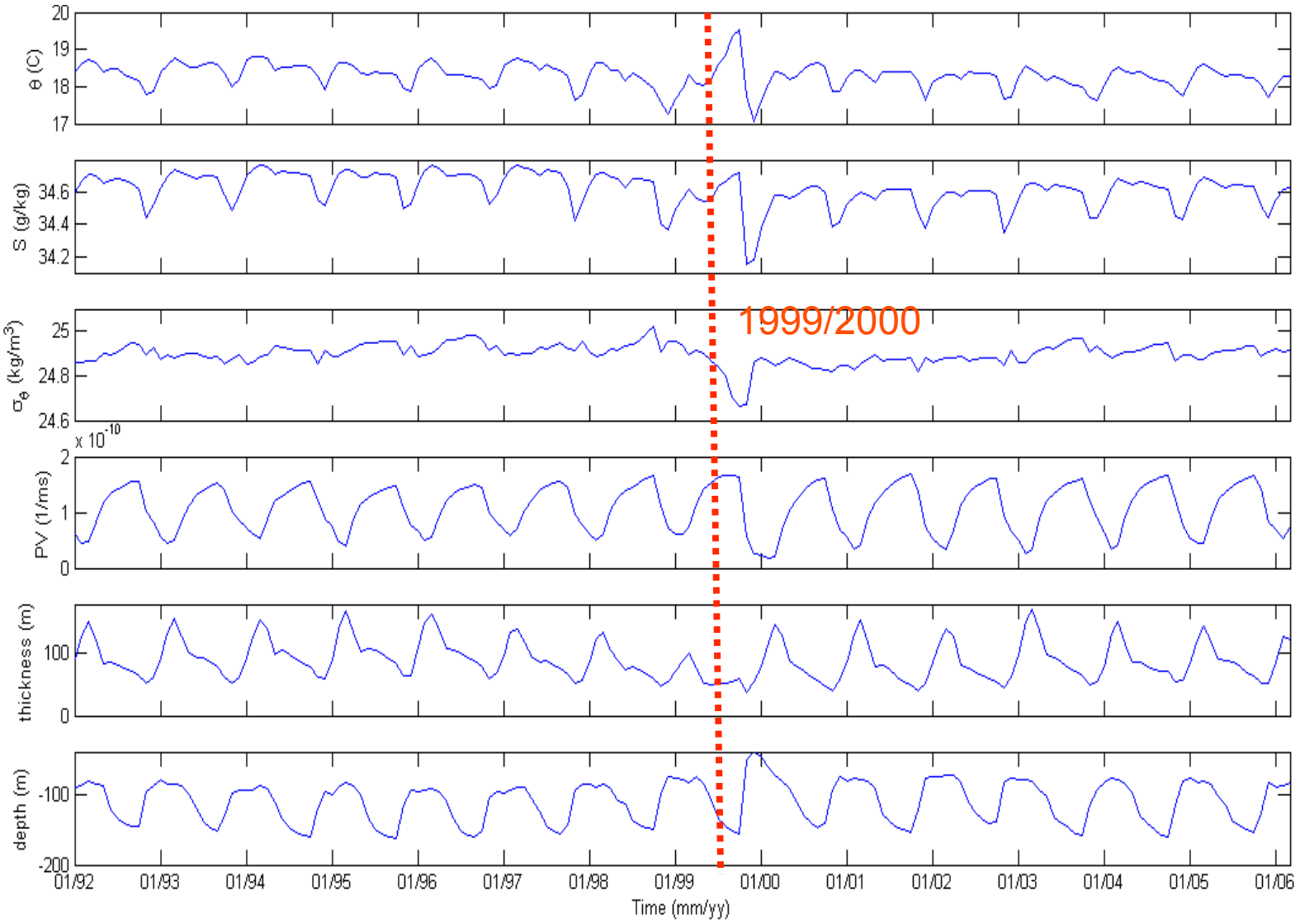


KESS, late May 2004



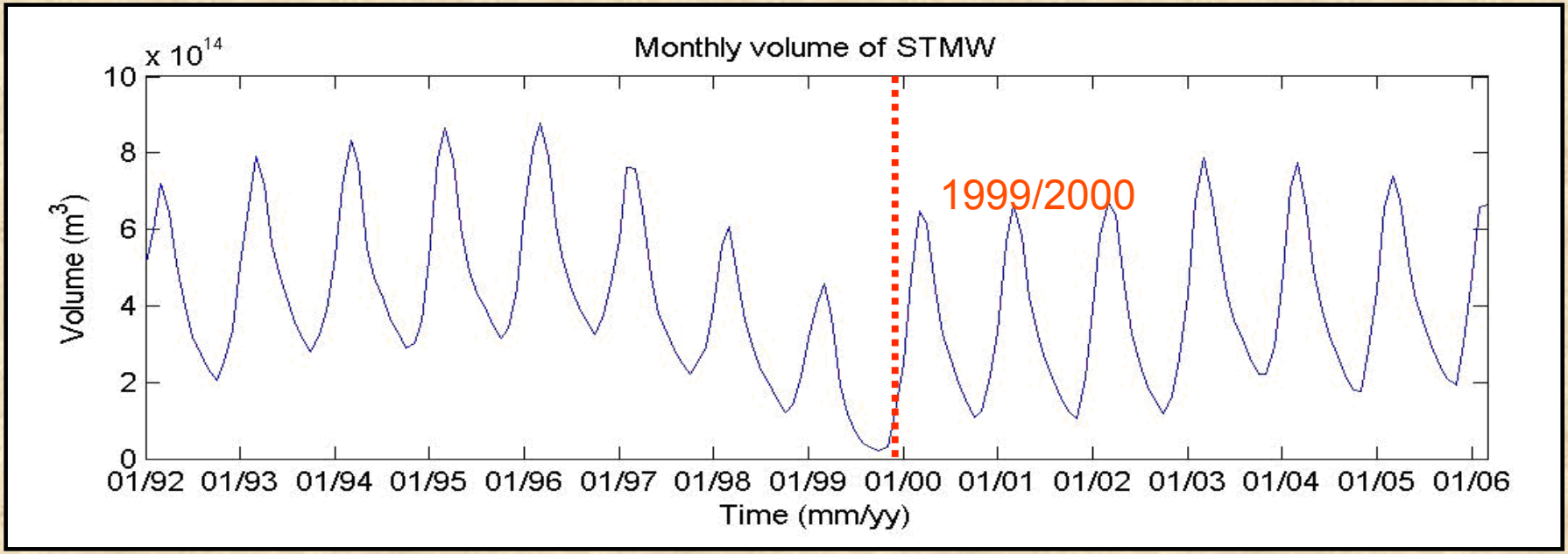
After Rainville,et al., 2007

Temporal variability: 3-D averaged features of STMW

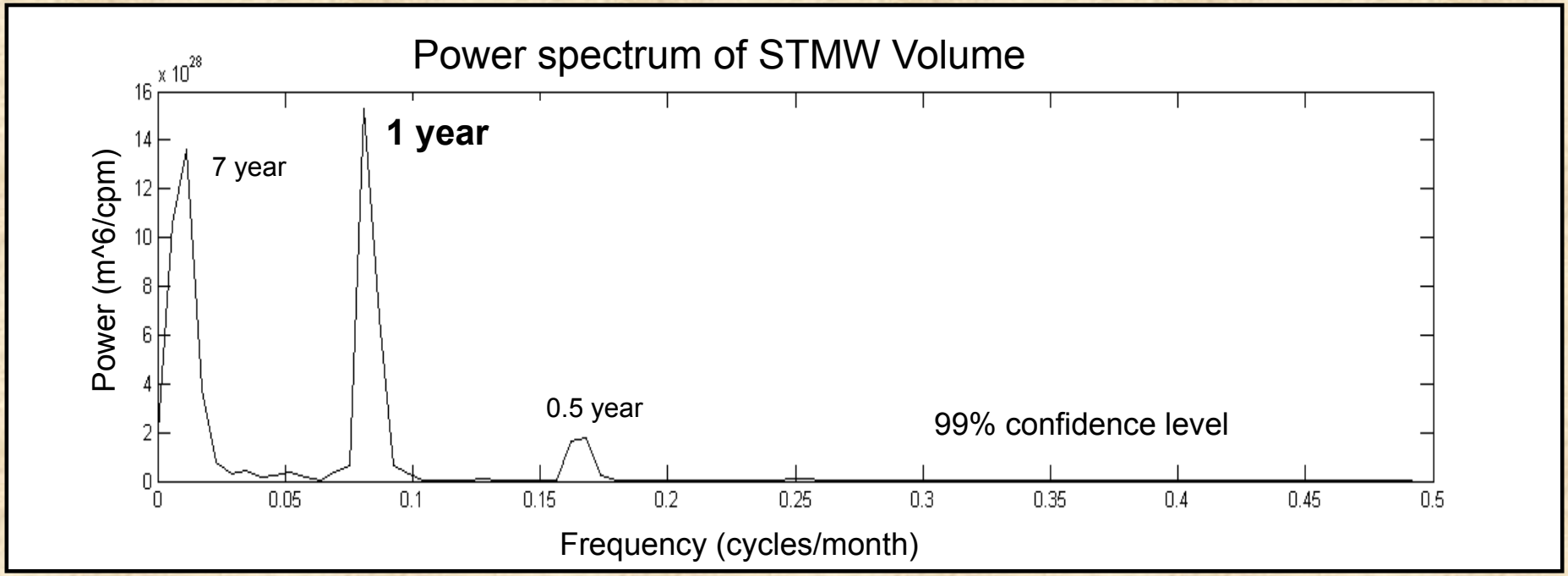


During 1999/2000, cooler, fresher, lower PV, lighter, thinner, shallower STMW

Temporal variability: STMW volume



Dominant signal for the STMW variability



Annual cycle is the most significant

Seasonality of STMW in climatological fields in MITgcm

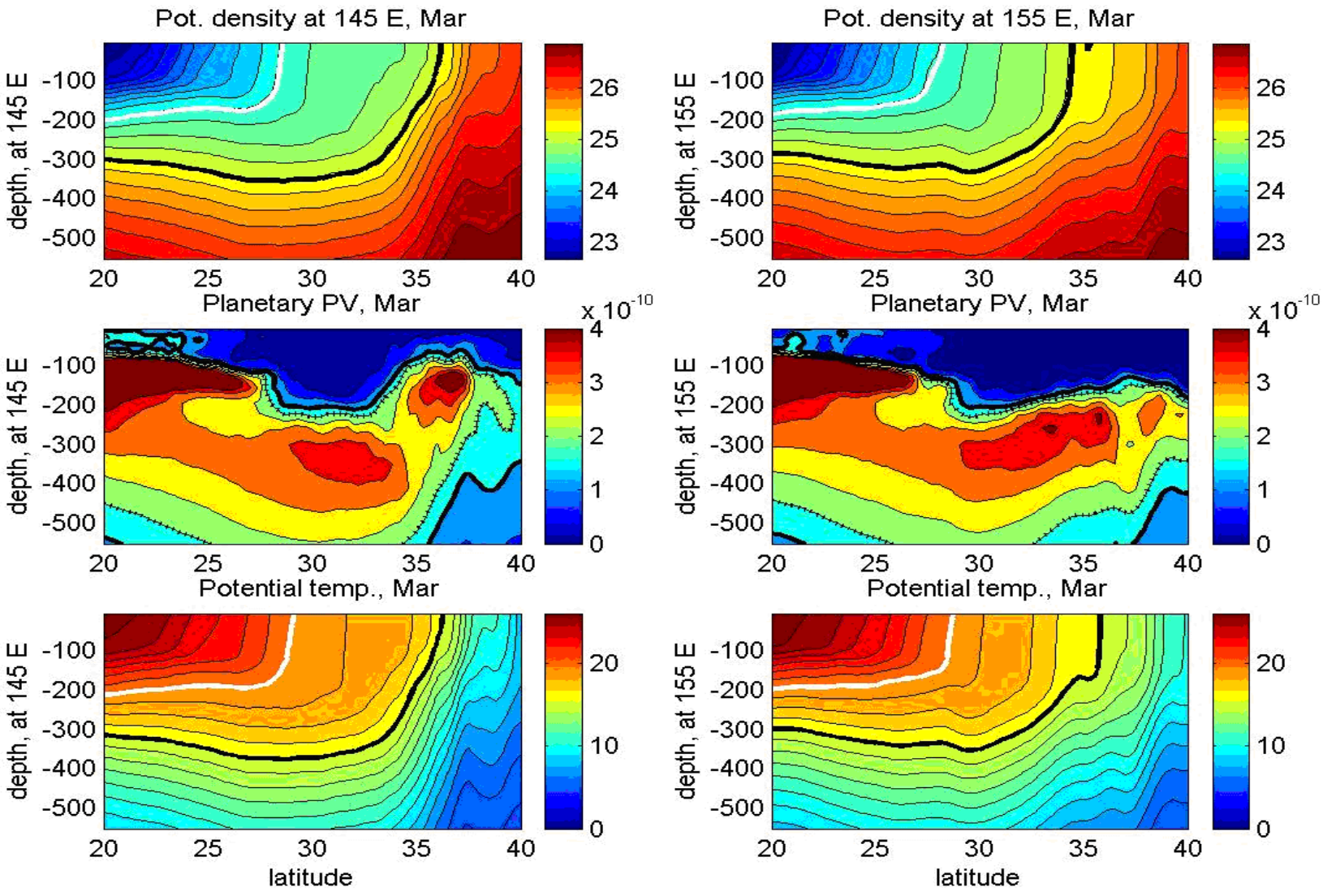
Take θ as an example:

$$\theta_{month}(lon,lat) = \frac{1}{14}\sum_{year=1992}^{2005}\theta_{year,month}(lon,lat) \quad (month=1,2,\ldots\ 12)$$

Where $\theta_{month}(lon,lat)$ is the calculated climatological field

Seasonality in climatological fields

-meridional cross section



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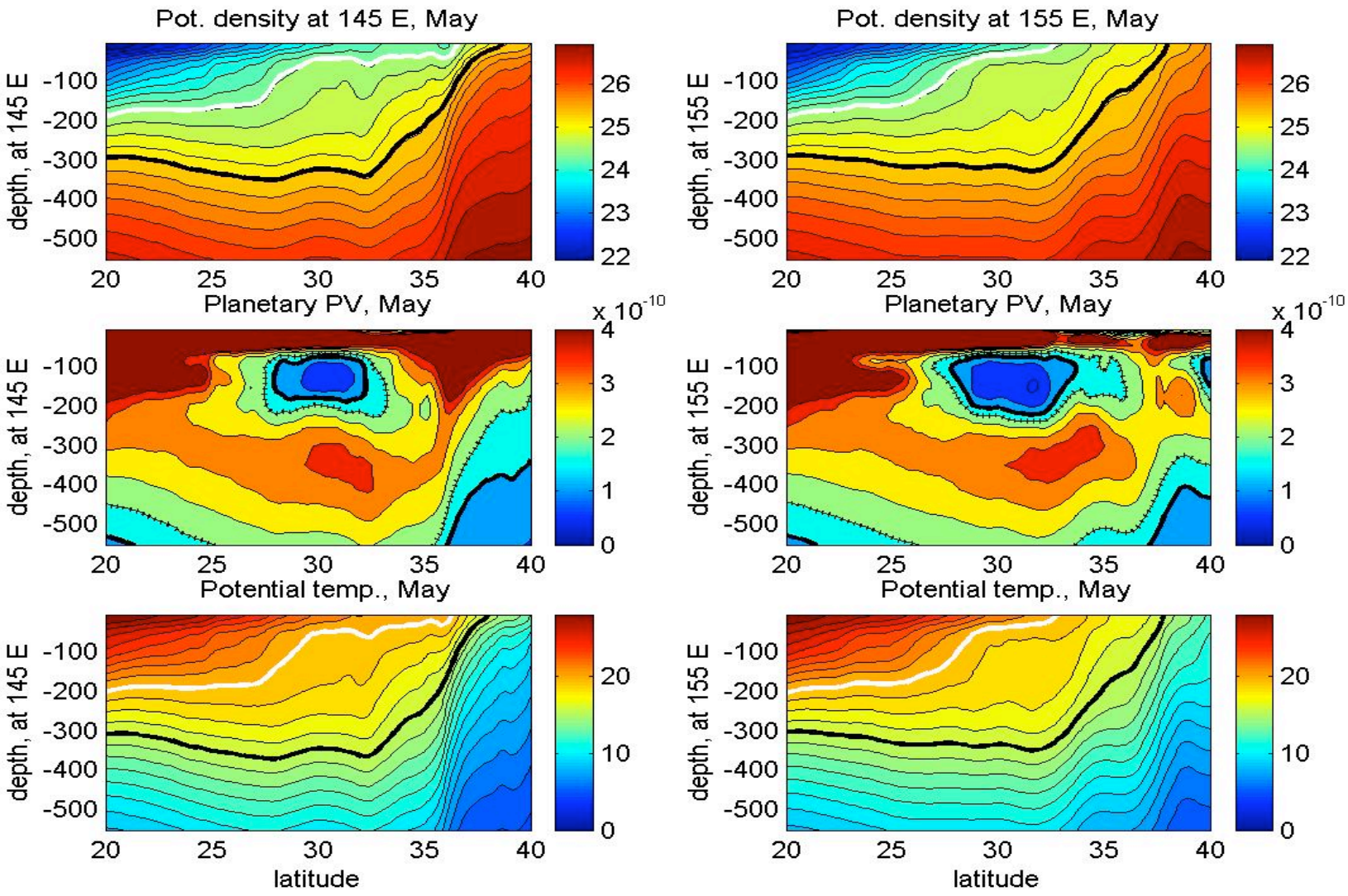

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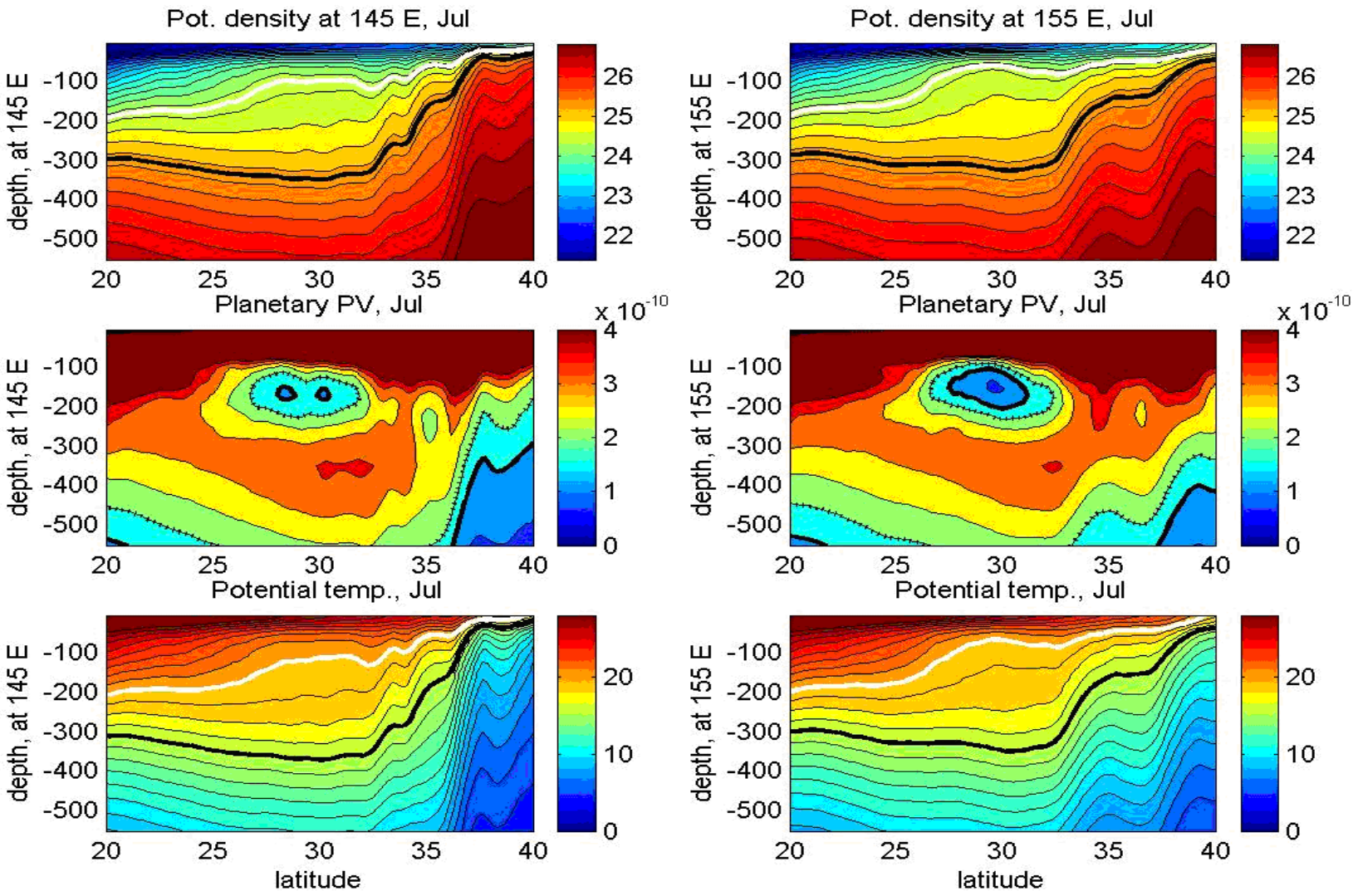

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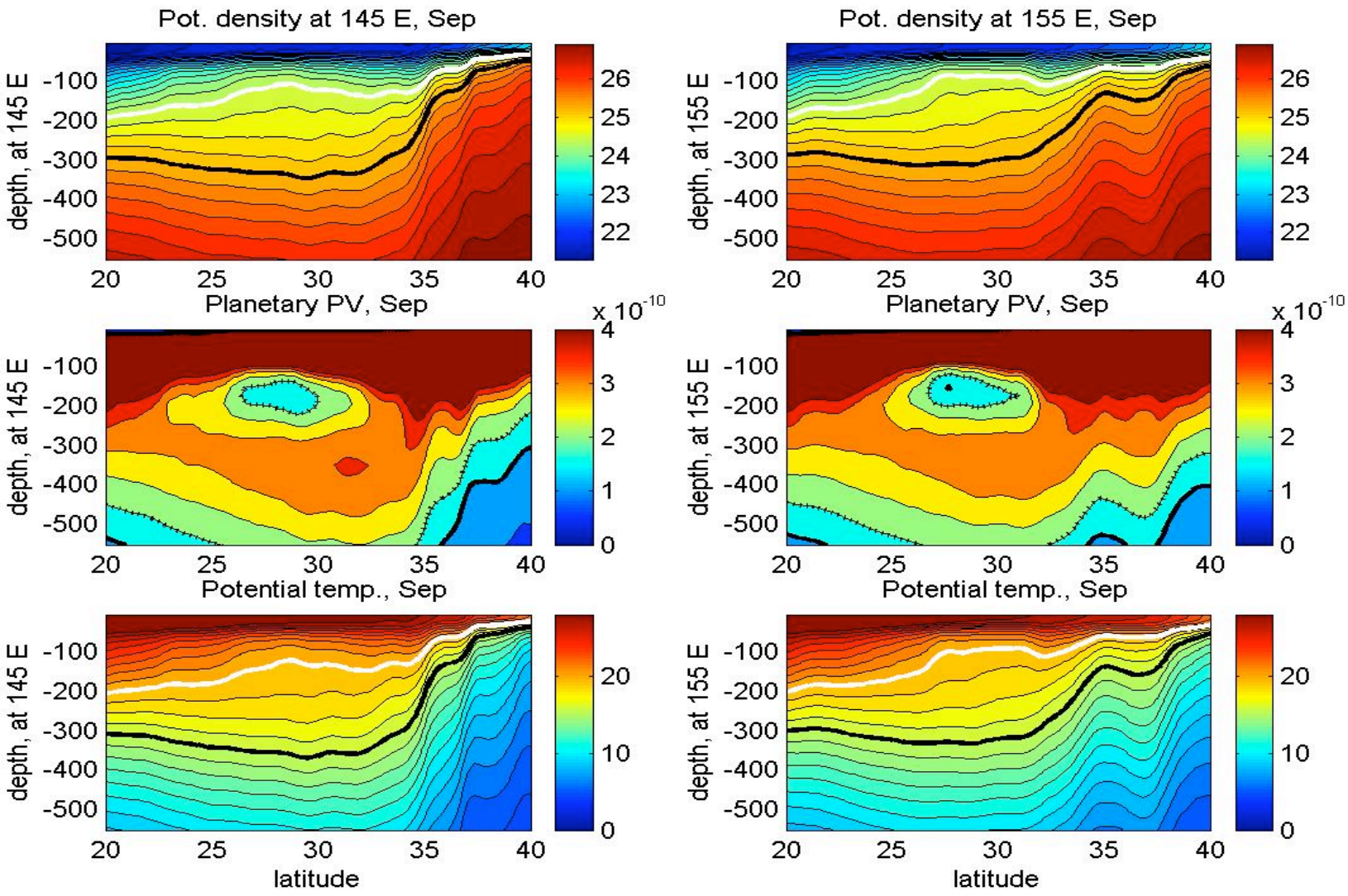
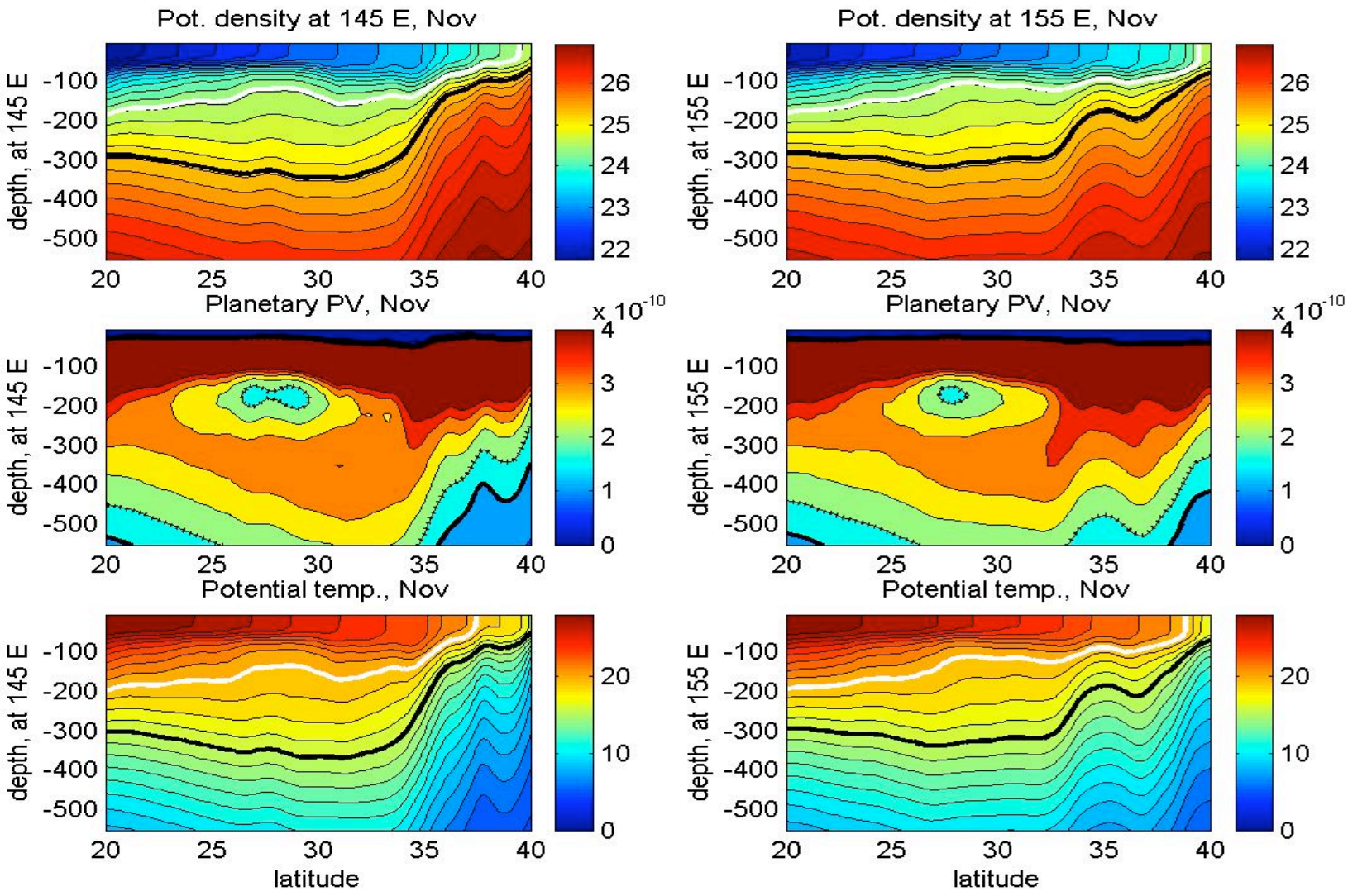


Results: Seasonality in climatological fields

-meridional cross section



Seasonality in climatological fields

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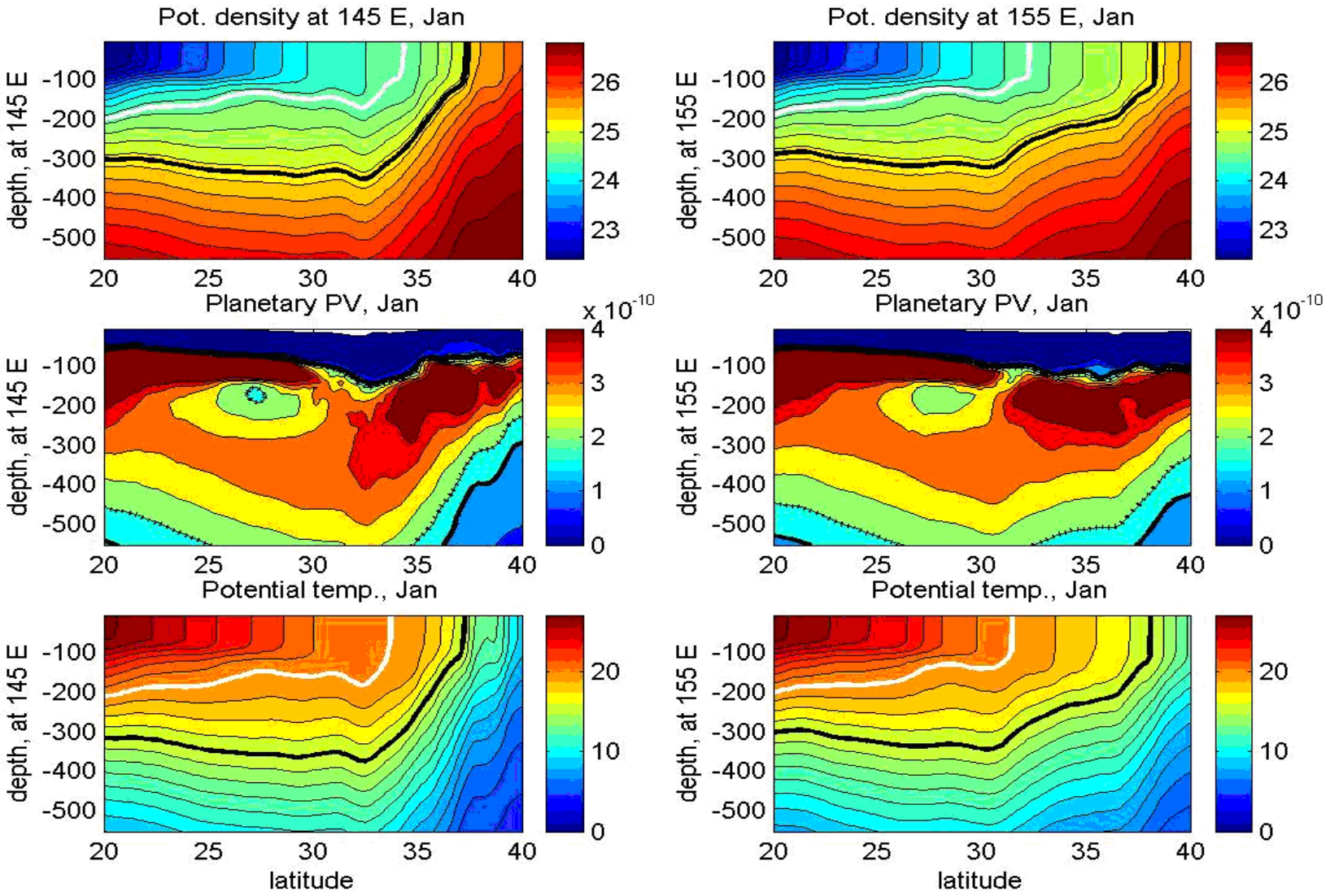
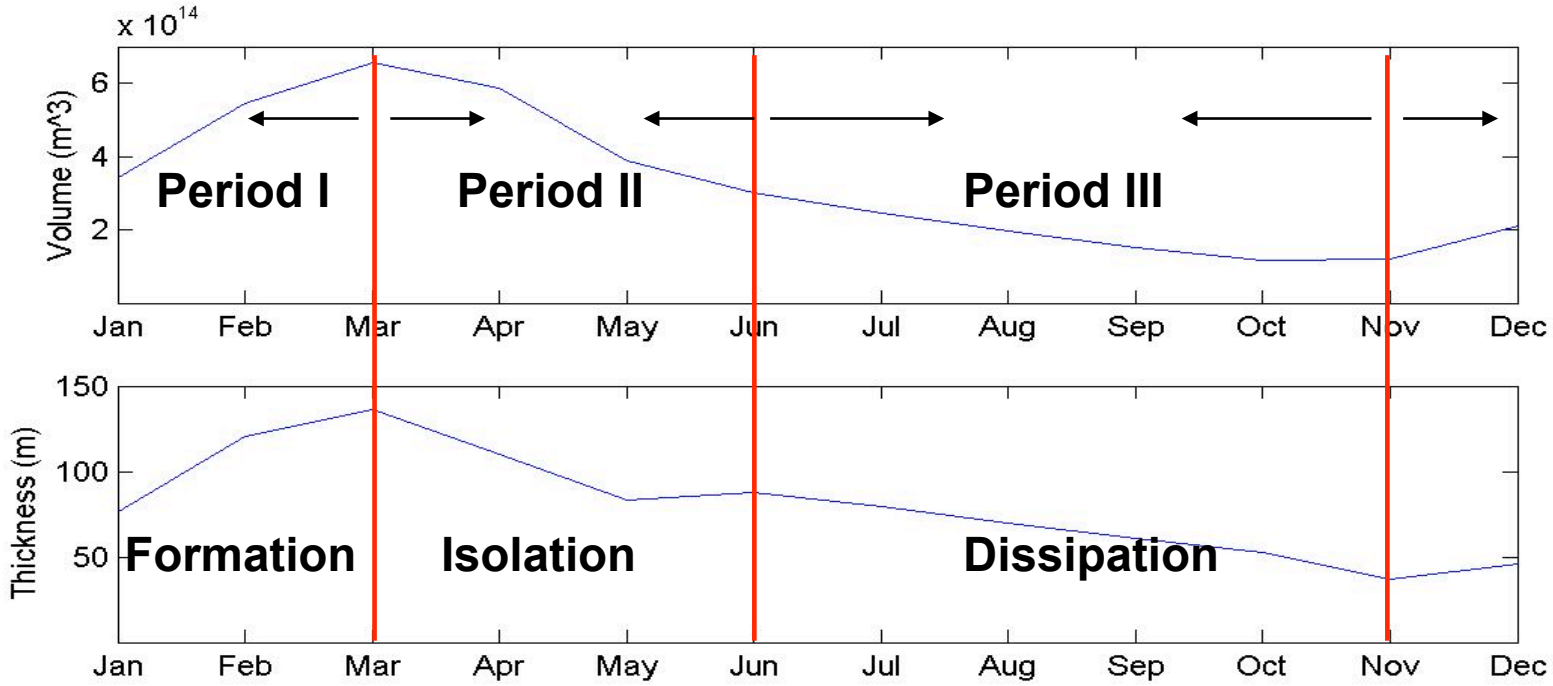


Results: Seasonality in climatological fields

-three time periods



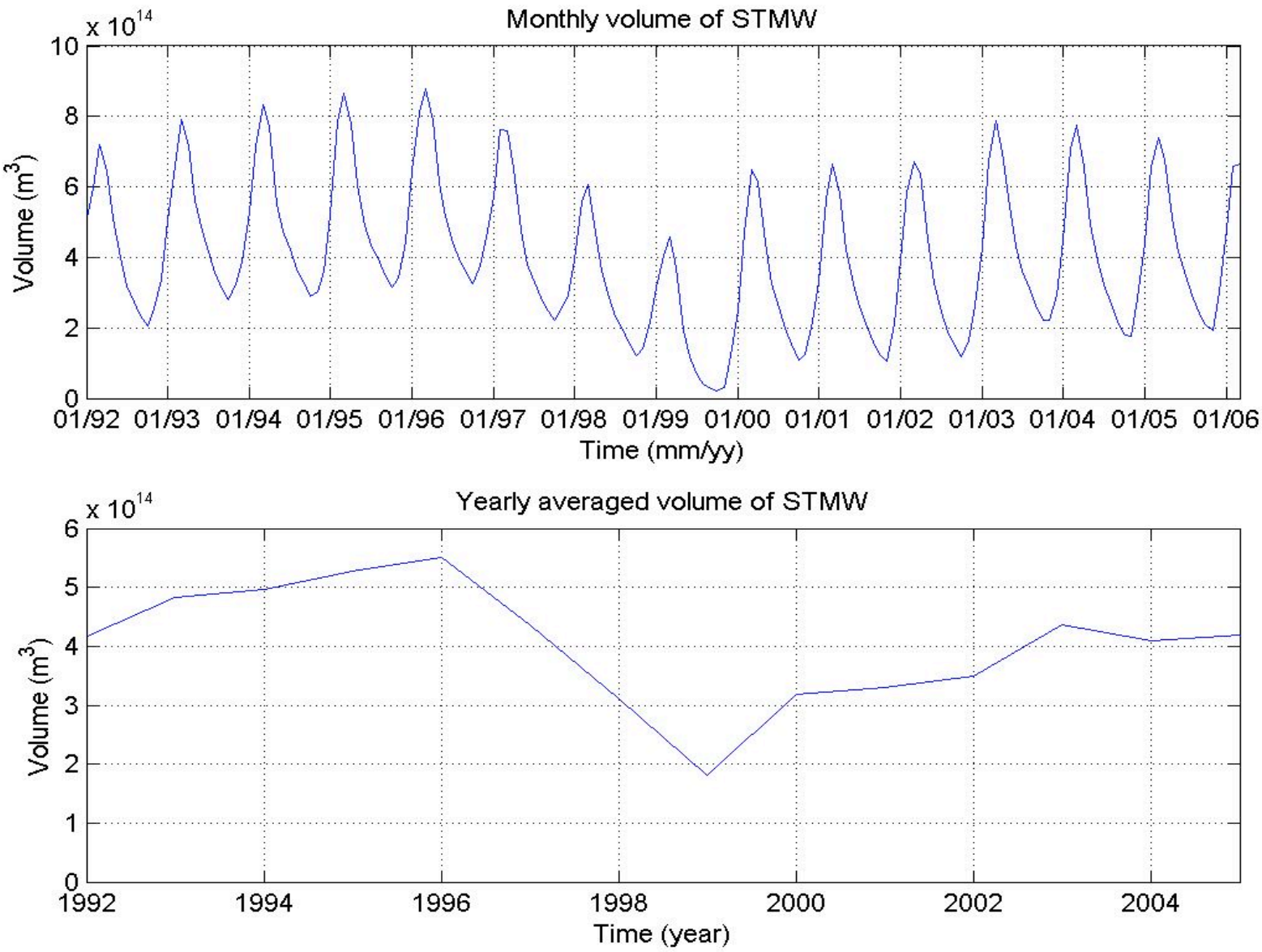
Period I: STMW formation (Nov~Mar)

Period II: STMW isolation (Mar~Jun)

Period III: STMW dissipation (Jun~Nov)

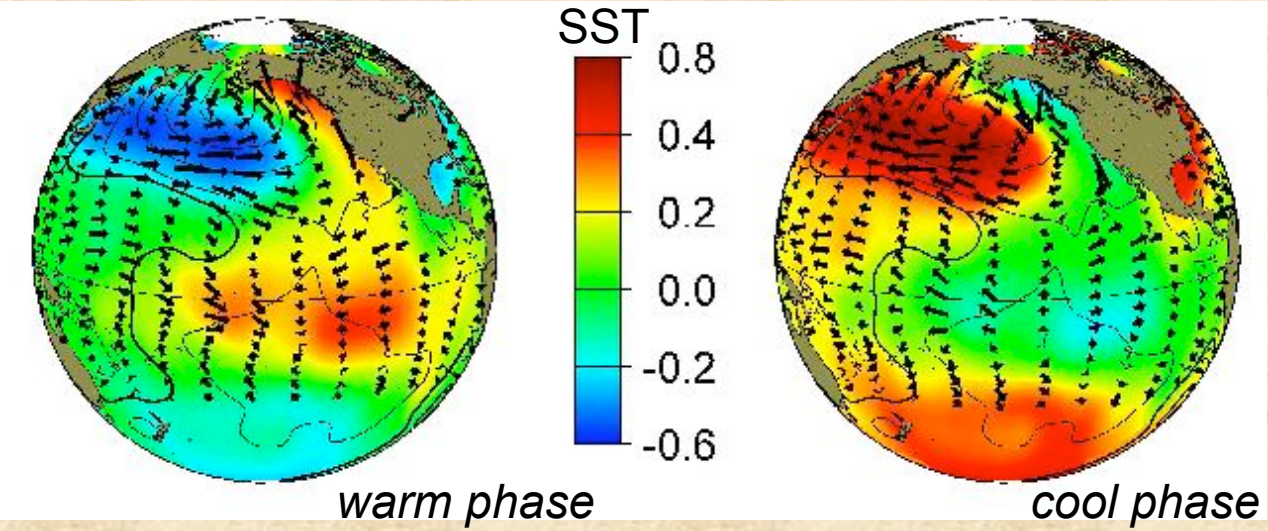
Interannual variability of STMW

STMW interannual variability



STMW variability and its relation to Pacific climate variation

The Pacific Decadal Oscillation (PDO)

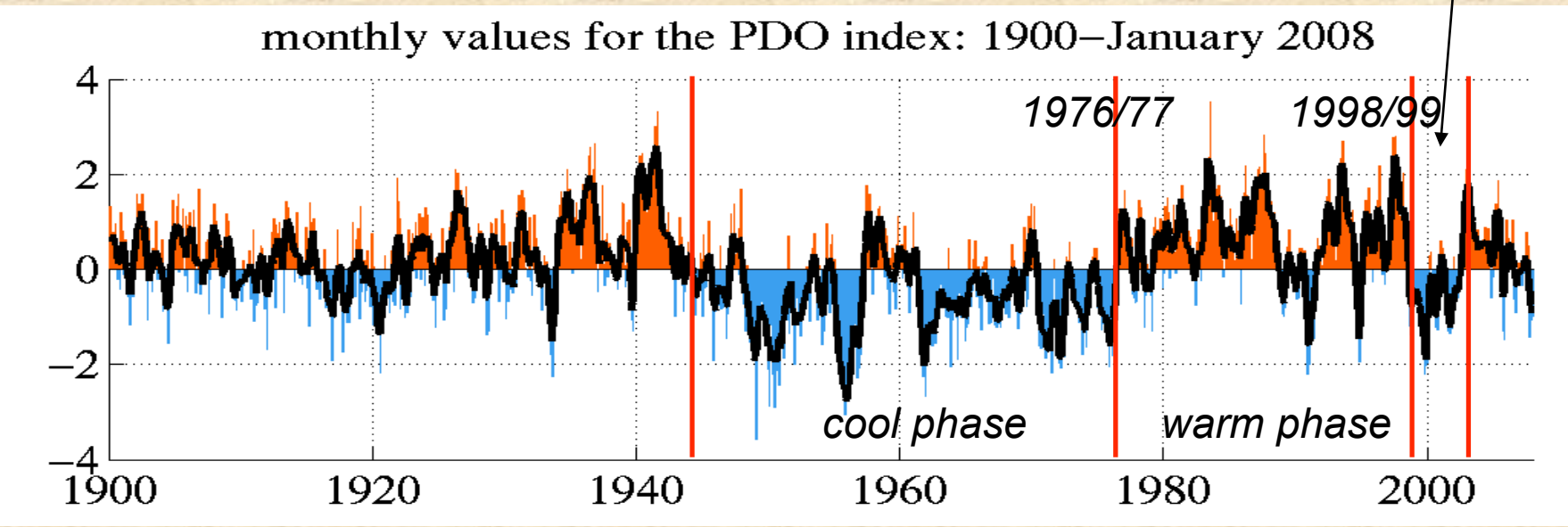


Warm phase:

cooler SST in STMW region

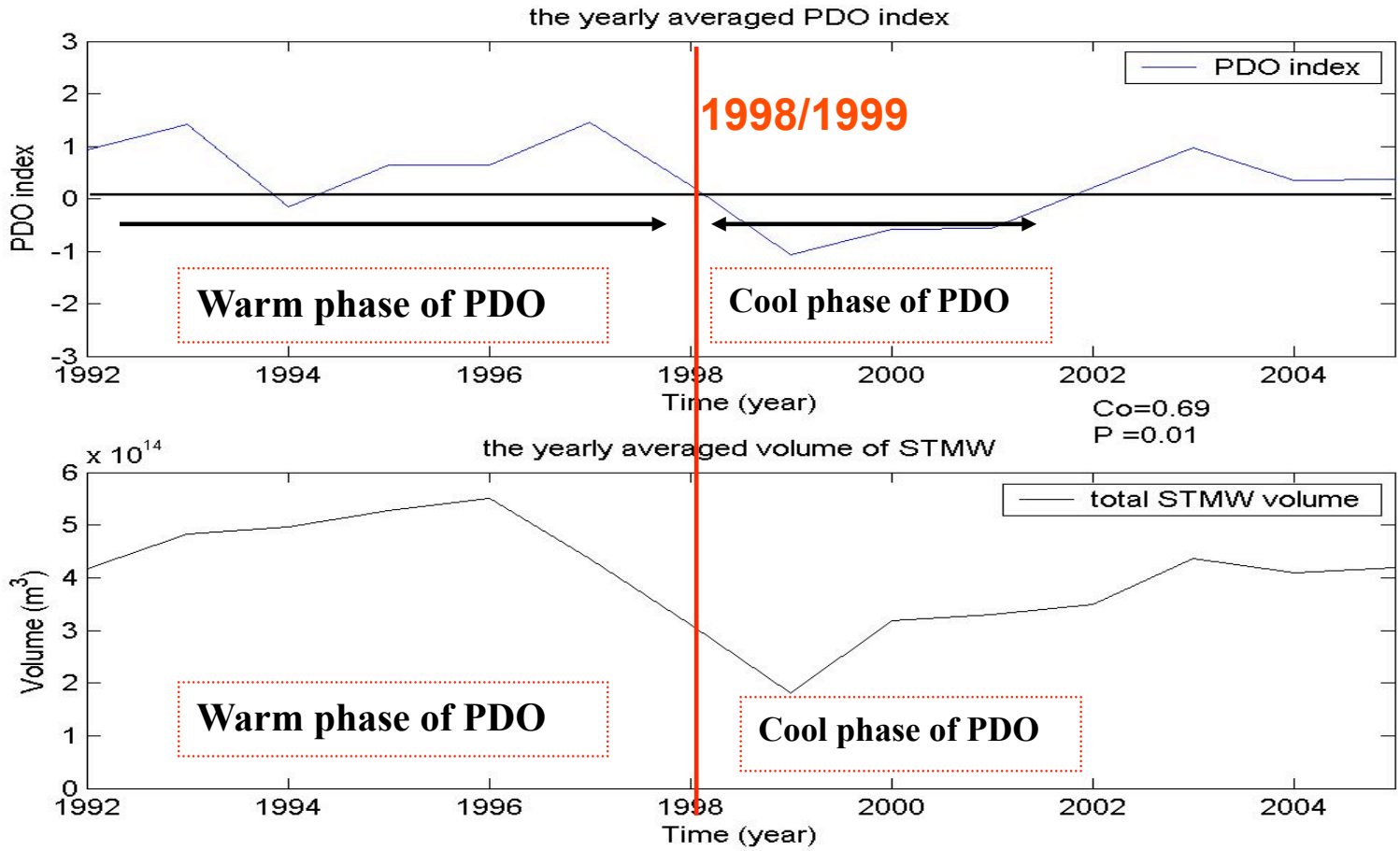
Cool Phase:

warmer SST in STMW region



www.jisao.washington.edu/pdo/

STMW Variability & PDO



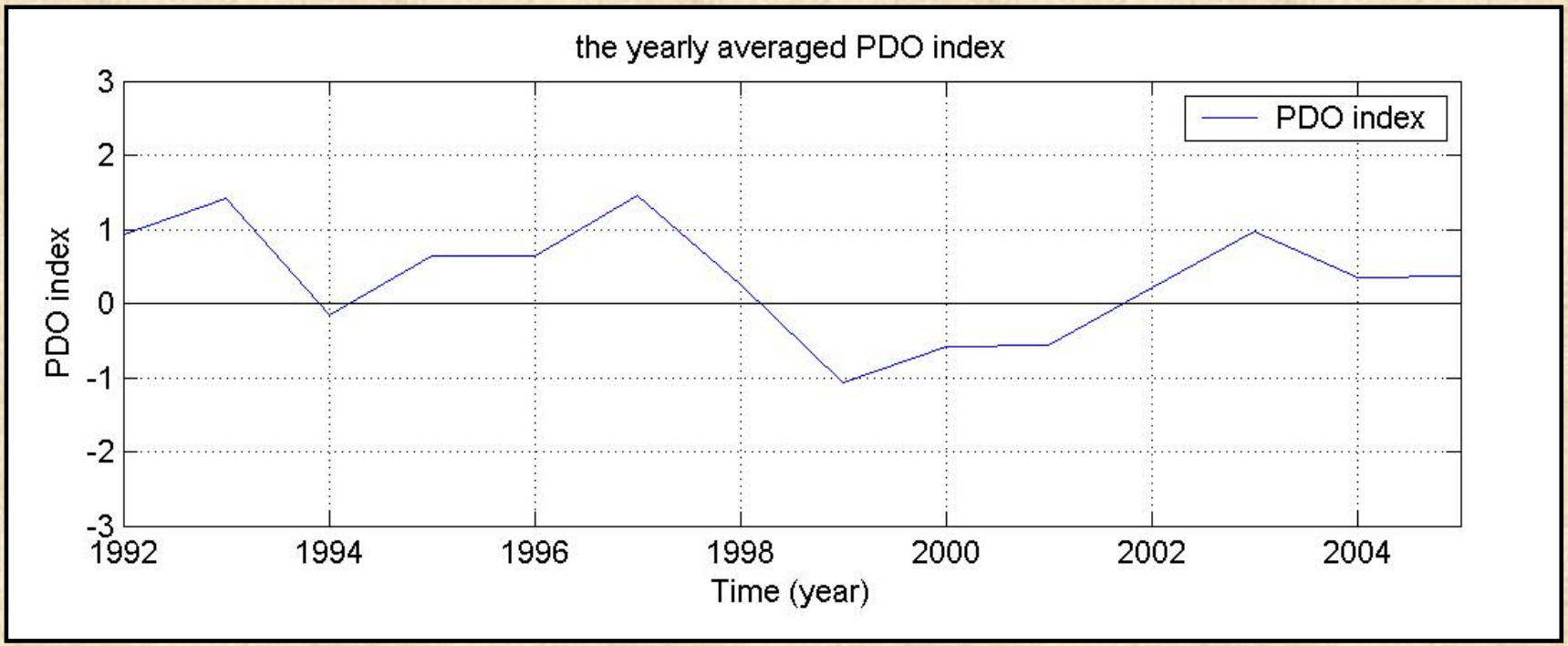
STMW variability is highly correlated with PDO index

Co=0.69, significant value=0.1 with 95% level of confidence

Connection between STMW & PDO: large scale atmospheric variations

PDO Index

The 1st EOF time coefficient of the SST north of 20 N in Pacific



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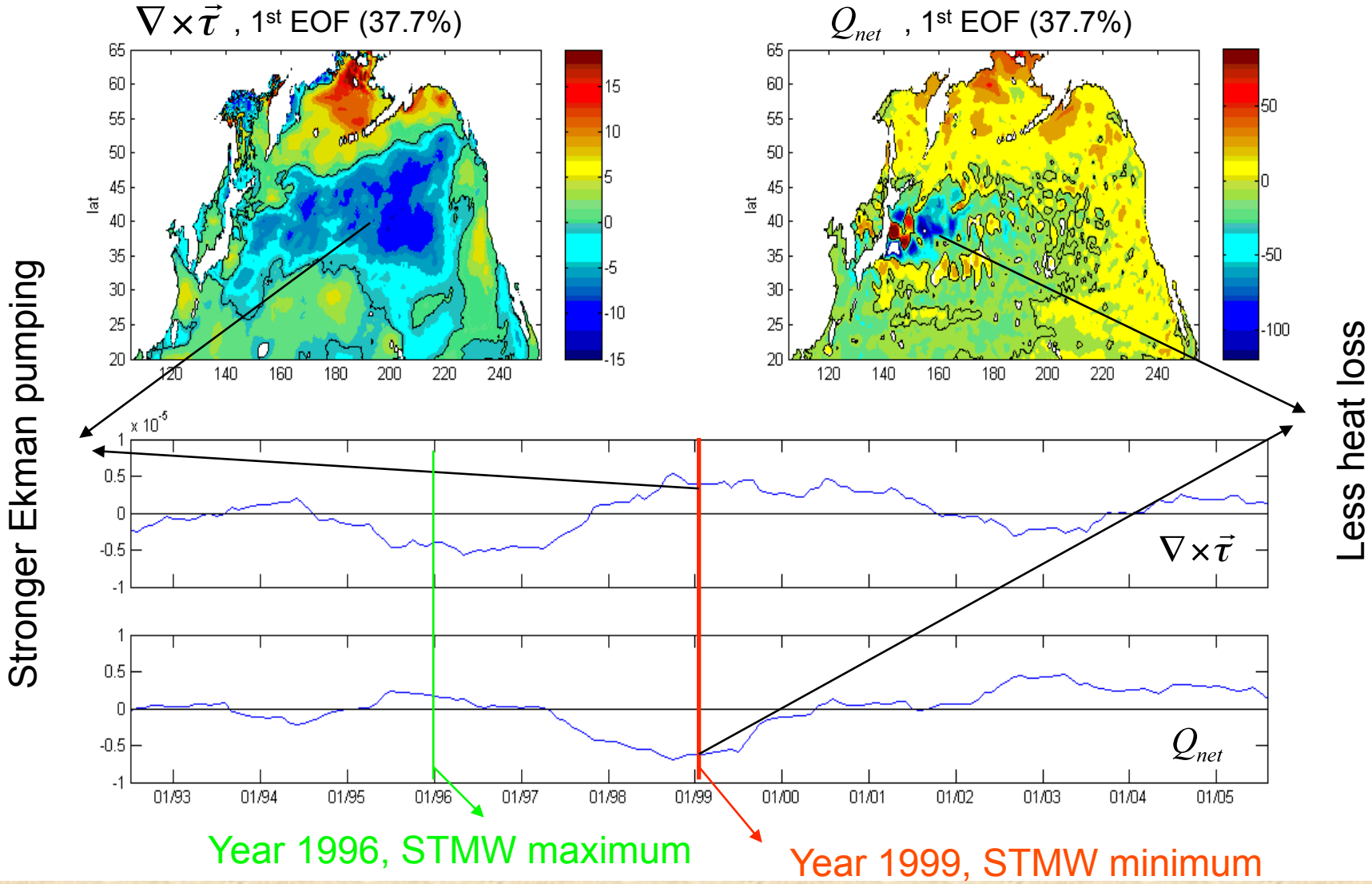

Summary (MITgcm)

- The dominant temporal pattern of STMW is seasonality, the annual cycle can be divided into formation, isolation and dissipation periods that correspond to distinct stages of STMW evolution

- An interannual signal is clearly seen in STMW variability as well, this lower frequency signal shows significant correlation with PDO index

- This likely results from the variations in the large scale atmospheric forcing: wind stress and air-sea heat flux

Theoretical frameworks and possible mechanisms of STMW variability

- Following Dewar et al 2005, a modified LPS framework may be established to describe STMW and its connections to large scale ocean-atmospheric circulation

- A PGOM (Samelson & Vallis, 1997) numerically approximates the solutions to this framework and describes STMW characteristics.

- PGOM experiments demonstrate that the interannual variability observed in the Cube 37 simulations can be driven by variations in the large scale air-sea heat flux and wind stress patterns seen in the NCEP reanalysis.

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- *Young-Oh Kwon (WHOI)*

Seasonality in climatological fields

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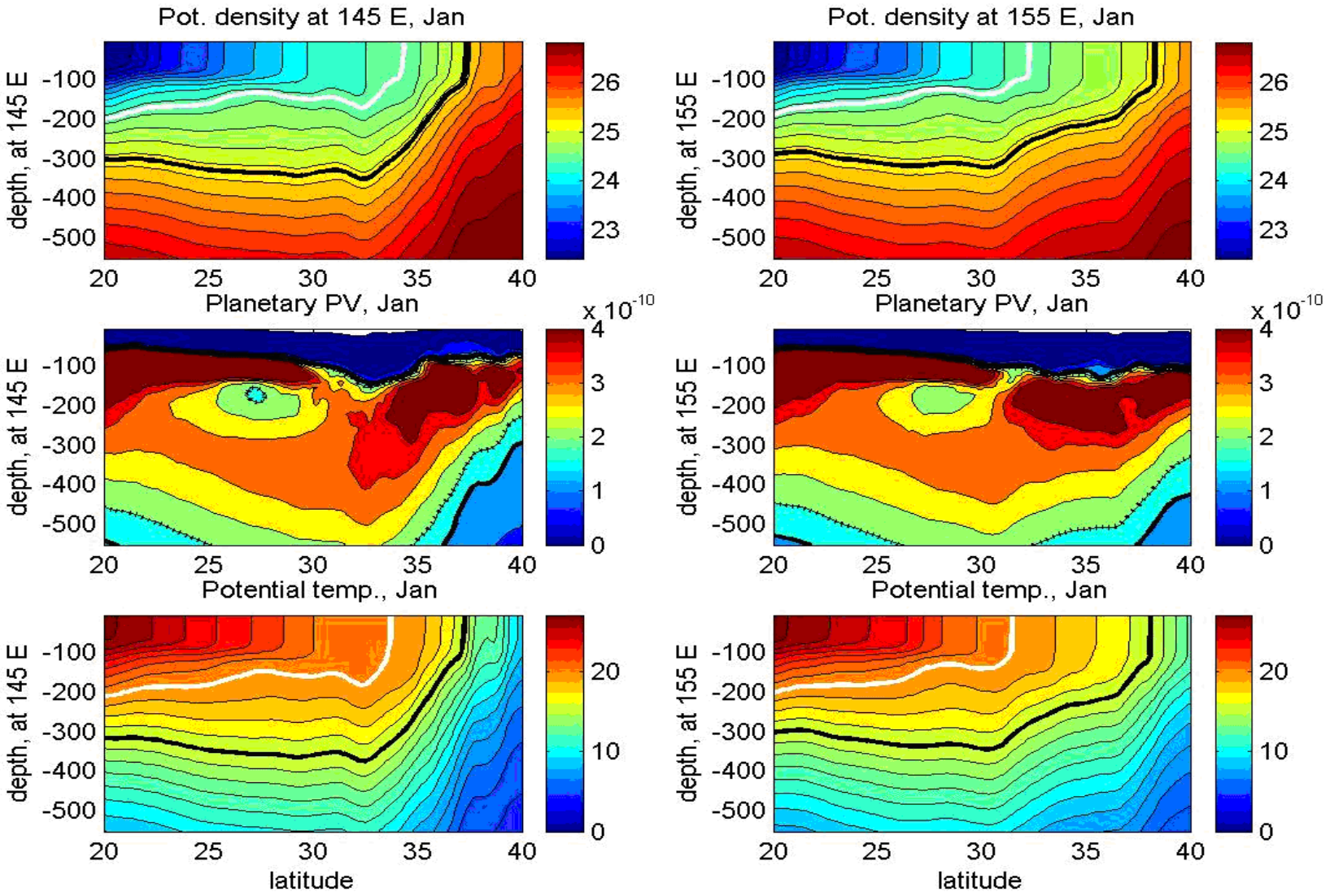

Summary (PGOM)

- PGOM representation of the modified LPS framework produces a distinct analog to STMW
- Within this model/framework, Ekman pumping is necessary for the existence and maintenance of STMW
- Quasi-realistic time varying atmospheric forcing experiments show variable large scale wind stress (Ekman pumping) and air sea heat fluxes can separately generate seasonal and interannual variability in STMW